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ENCAPSULATION, ELECTRONICS, ECCOFOAM

BY

FRANCIS N. LeDOUX

NOVEMBER 1965

GODDARD SPACE FLIGHT CENTER

GREENBELT, MARYLAND

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EFFECTIVE DATE: 3/23/64

FOREWORD

The greater percentage of all encapsulation of electronic components and associated circuitry by the Structural and Mechanical Applications Section at Goddard is performed using a polyuerthane foam in place resin. The resin most generally used is Eccofoam FP with a 12-6 catalytic agent. In using this material it was found that, without definite controls of temperature, humidity and proper amounts of resin mix the resulting foam encapsulant would vary considerably, greatly effecting its density and structural homogeneity.

A series of tests were therefore conducted so as to ascertain the proper mold and/or resin temperatures, and the amounts of resin to catalyst that would have to be used at an average relative humidity in order to obtain a density of cured foam of from 8 to 10 lbs. per cu. ft. However, before any information gained from these tests could be applied to our applications a technique had to be developed to ascertain the exact volume of a void to be filled.

It was found that the requirements for the end product could be met if the herein stated technique and procedure is followed.

Francis N. LeDoux

1.0 Introduction

1.0.1 In the development of payloads for space applications it is required that many and varied types of resins, sealants and adhesives be used to achieve the desired results. Their purposes of use are also varied, however, this procedure and developed technique will deal only with one, Eccofoam FP, a foam in place resin used primarily to effect light weight structural reinforcement of embedded electronic components and associated wiring.

2.0 Material

Before using Eccofoam FP heat its contents in its container to 165°F then allow to cool. This is required only once. CAUTION: this operation is to be performed only while under the fume hood. Stir contents constantly while heating.

3.0 Molds

In order to properly contain the electronic component module and embeddment resin a mold must be made. An example of such a mold is shown on page 9 sketch A.

The molds used for encapsulating the modules are usually made of aluminum, however, this is not considered a requirement as many other metals would also be suitable. The tests that were made in developing this potting technique were all conducted using aluminum molds

4.0 The electronic modules or cards that are to be encapsulated should contain relief holes so as to allow a more even expansion of resin on both faces of card. Where this is not possible it is recommended that a stand off be affixed to the card so as to prevent warping of card. The bottom face of the electronic supporting card should have, if possible, stand offs placed (rule of thumb) approximately two inches apart from each other. Your attention is drawn to sketch B, page 10 .

5.0 Example

It is required that an electronic card be embedded in Eccofoam FP. It is also required that the density of foam be from 9 to 10 lbs./cu. ft. In order to fulfill these requirements the following procedure is recommended.

5.0.1 Determine the volume of void to be filled.

(a) Fill the void to be encapsulated with Cream of Wheat.

(b) Pour off wheat into ml graduate (1 ml = 1 cm^3).

(c) Number of ml is equal to the number of cubic centimeters volume.

(d) Convert the number of cm^3 to in^3. Multiply cm^3 x 0.06102 to obtain in^3.

(e) On nomagraph, page 8 , locate the amount of resin and catalyst required to fill the determined void.

5.0.2 Place electronic component and/or card into the potting mold.

5.0.3 Determine the number and location of stand offs, remove card from mold.

5.0.4 Affix stand offs to card.

5.0.5 Determine areas that are to be left free of potting material i.e., plug connectors, trim pots or other adjustables.

5.0.6 Fabricate and place needed plugs to protect areas determined in 5.0.5. Teflon is an ideal material to use, however, Duxseal may also be used for this purpose if the area is not too large.

5.0.7 Spray all inside surfaces of the mold with teflon mold release.

5.0.8 Put silicone mold release on pin connectors even if they are covered with Teflon or, dummy plug.

5.0.9 Place the electronic card into its mold.

5.1.0 Place entire assembly into oven including the top plate of mold and allow to remain until mold body has reached a temperature of 60°C.

5.1.1 Weigh out required amount of Eccofoam liquid resin (5.0.1 d) into a paper cup.

5.1.2 Weigh out required amount of 12-5 Eccofoam catalyst into a separate container (5.0.1 d).

(a) One method is to use a hypodermic syringe in weighing catalyst (1 cc = 1.1818 grams) multiply grams x .837 to obtain equivalent no. of cc.

5.1.3 When assembly has reached the required soak temperature remove from oven and place on bench under fume hood.

5.1.4 Place catalyst into cup containing the resin.

5.1.5 Mix rapidly using a drill motor and special mixing blade as shown in Sketch C, page 11 .

NOTES

(a) Mix should be completed in 30 to 45 seconds (until a slight reaction is noted, i.e., a cherry red color of the batch will change to a light pink).

(b) Paper cups must be free of grease or wax. Do not use any container that has any film on it.

5.1.6 As quickly as possible distribute the resin mix as evenly as possible over the electronics card that was previously placed into the mold.

5.1.7 Quickly place mold cover, that has previously been coated with spray mold release, upon the mold body.

5.1.8 Immediately place C-clamps in position around edge of mold and tighten finger tight. See example, sketch D page 12

5.1.9 Place entire assembly into oven preheated to 60°C and cure for approximately one and one-half (1-1/2) hours at 60°C. Molds having volumes greater than 700 cc and/or thicker walls than mold shown in sketch B, page 10 should be allowed to remain in oven for a two hour cure. The converse is also true. If a mold volume is less than 400 cc and thinner walls a cure may be obtained in approximately 1 hour at 60°C.

5.2.0 After cure has been completed allow mold to cool to room temperature before removal. If use time is critical rapid cooling can be obtained by placing entire mold and clamping assembly into a refrigerator.

5.2.1 Cut away excess potting material from mold.

5.2.2 Remove clamps and mold cover. A thin blade knife will aid in removal of the cover

5.2.3 Apply, with fingers, a slight pressure around edges of potted card so as to remove card from mold.

5.2.4 Trim rough edges, remove protective plugs and dexseal.

NOTES

5.2.5 Conditions which affect density.

5.2.6 Mold Pre-Heat

The higher the heat the lower the density.

5.2.7 Size of Pour

The larger the amount of pour the lower the density.

5.2.8 Mold Restraint

The less restraint the lower the density.

5.2.9 Humidity

The higher the relative humidity the lower the density.

5.3.0 Mold Material and Heat Dissipation

The higher the rate of heat loss, the higher the density.

5.3.1 Standard conditions

(a) Mold pre-heat 60°C

(b) Humidity average 47%

(c) Mold material 6061-TG aluminum 1/4" thick wall (Sketch D, page 12)

CAUTION:

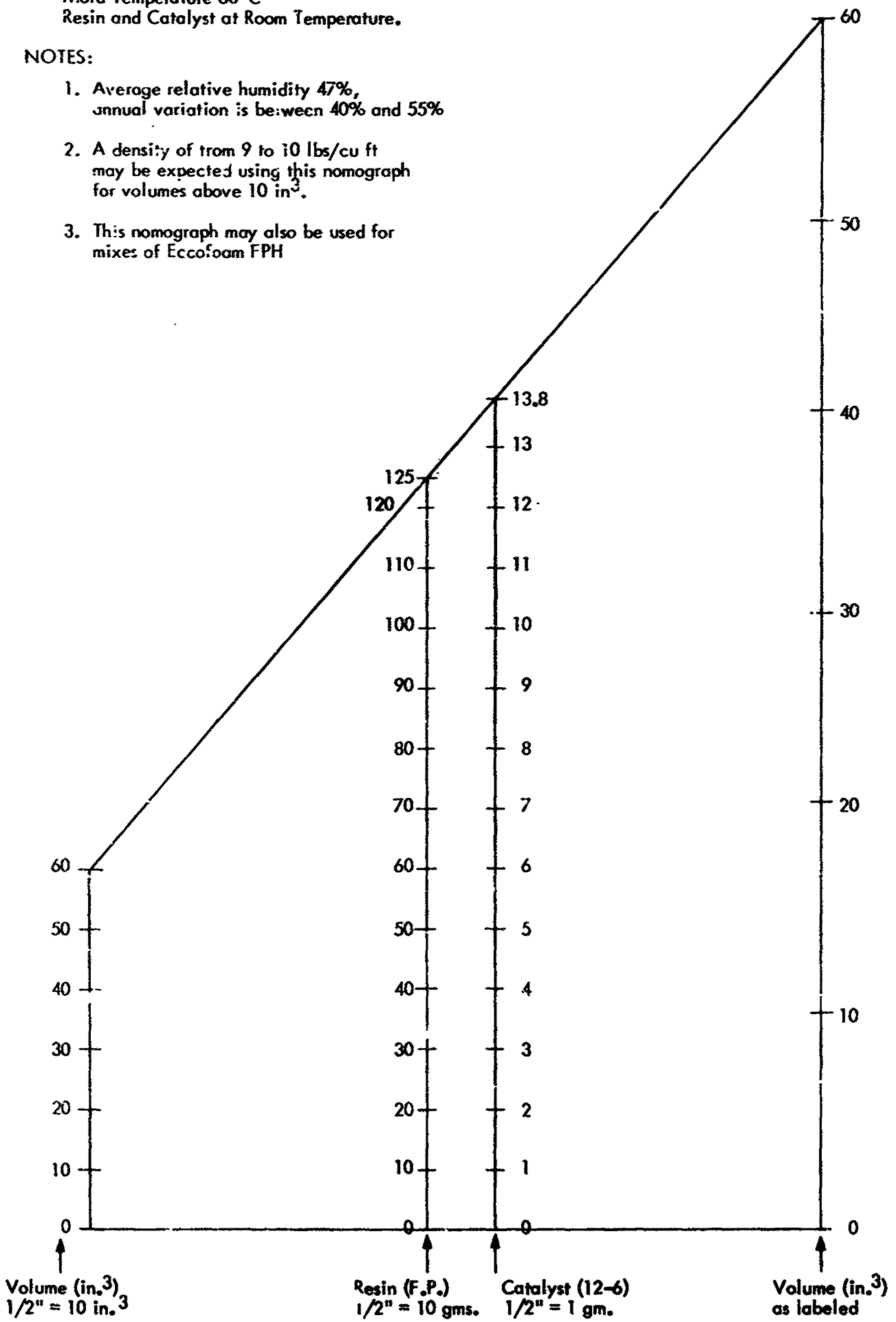
When specifying Eccofoam FP as an encapsulant it must be understood that the finished product will not be subjected to temperatures above 50°C. Heat from any source above 50°C will tend to distort the encapsulant and create undue stress on components. If finished product is to be subjected to temperatures above 50°C but, no more than 125°C, Eccofoam FPH must be specific.

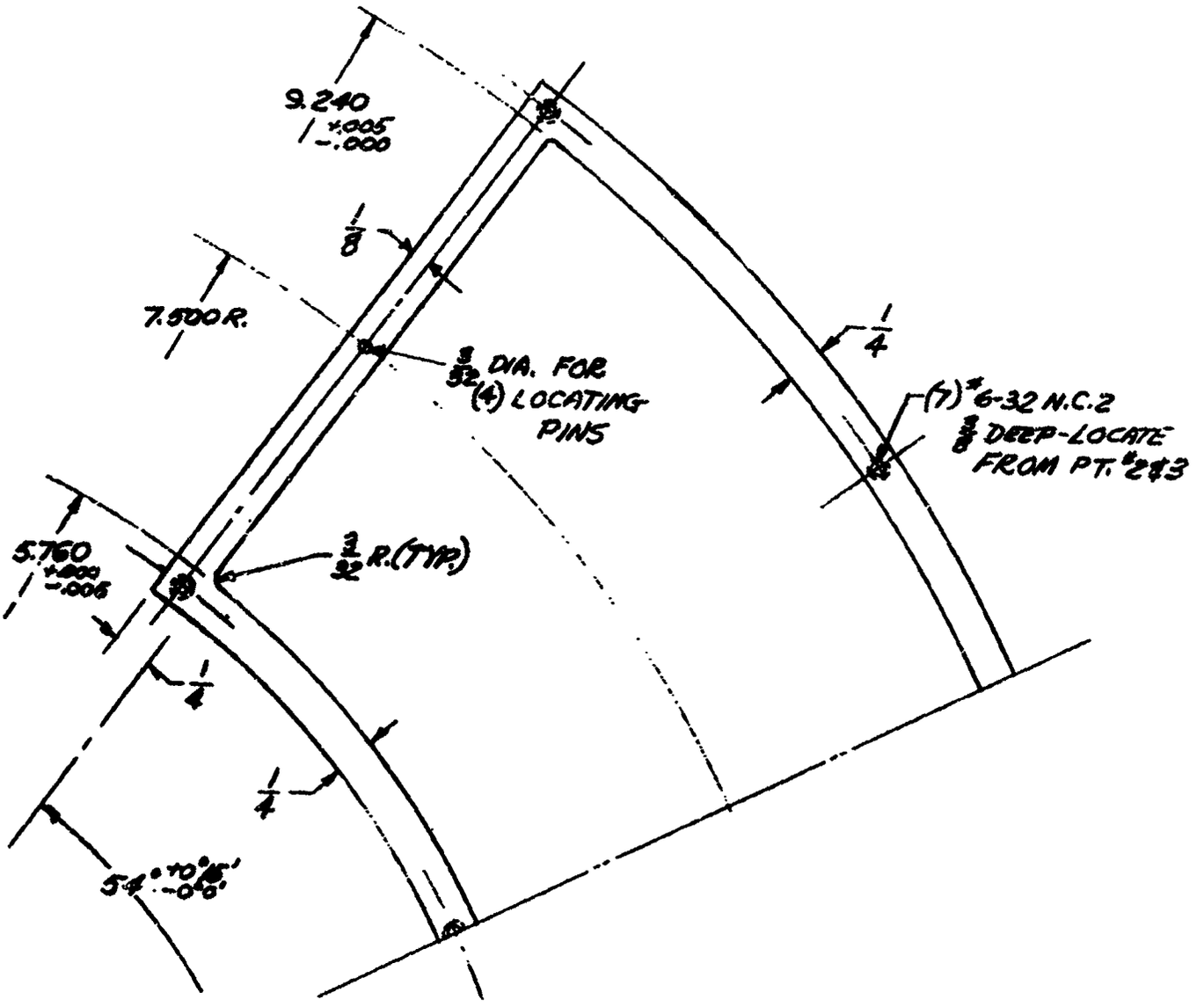
NOMAGRAPH FOR ECCOFOAM FP AND CATALYST 12-6.

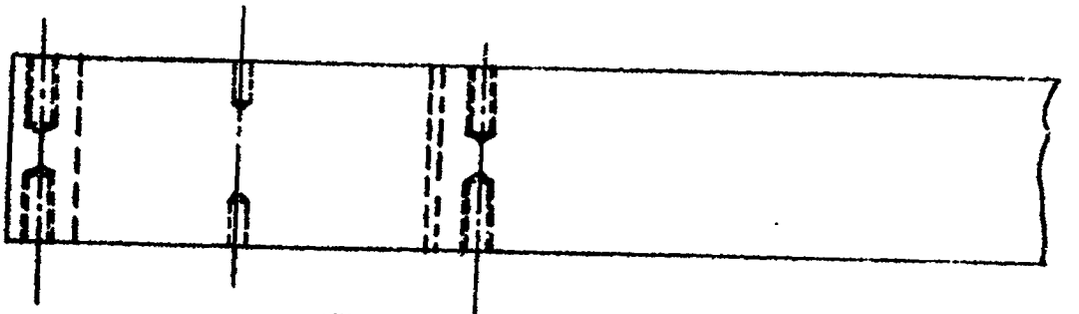
Mold Temperature 60°C
Resin and Catalyst at Room Temperature.

NOTES:

1. Average relative humidity 47%, annual variation is between 40% and 55%
2. A density of from 9 to 10 lbs/cu ft may be expected using this nomograph for volumes above 10 in^3.
3. This nomograph may also be used for mixes of Eccofoam FPH

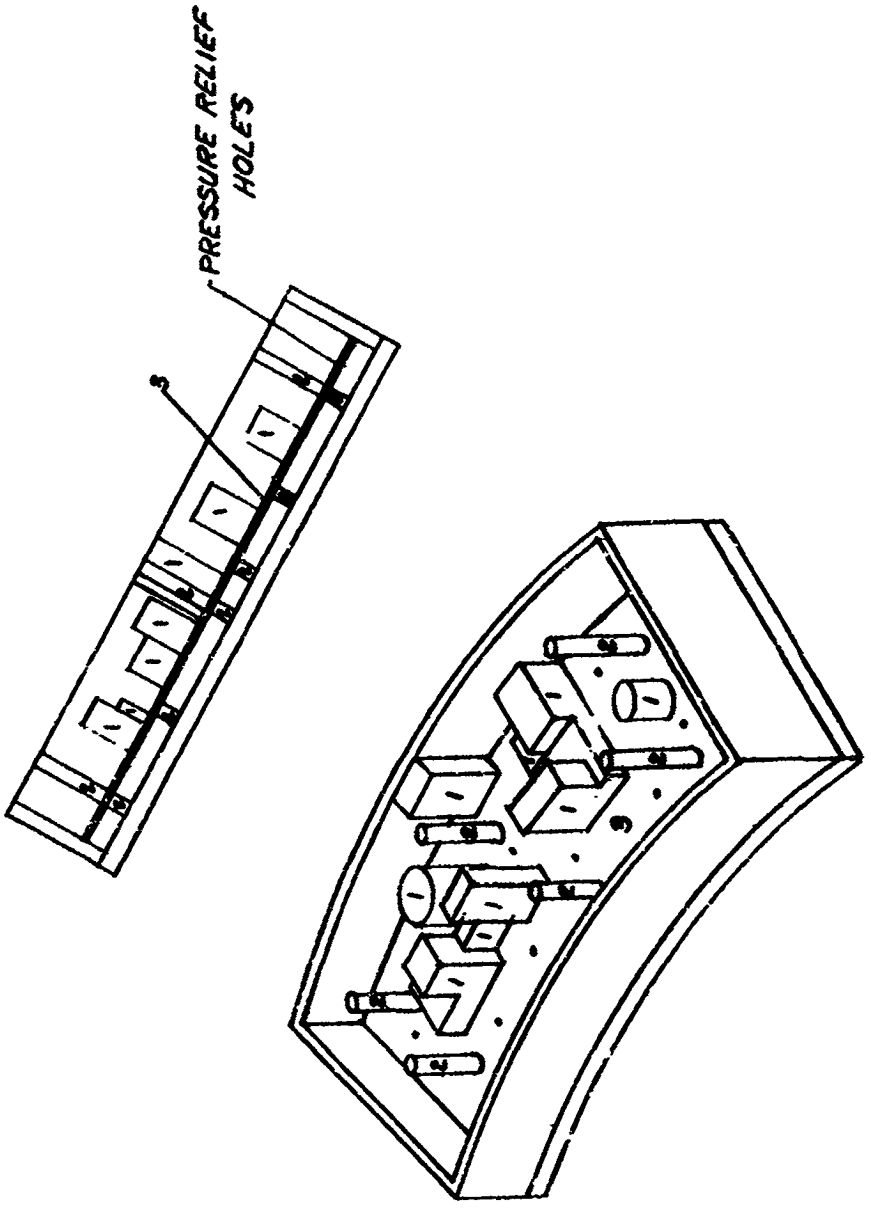




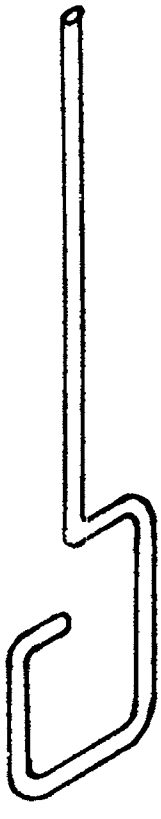


(1) FRAME, POTTING MOLD
MAT'L - 6061-T6 ALUMINUM

Sketch A

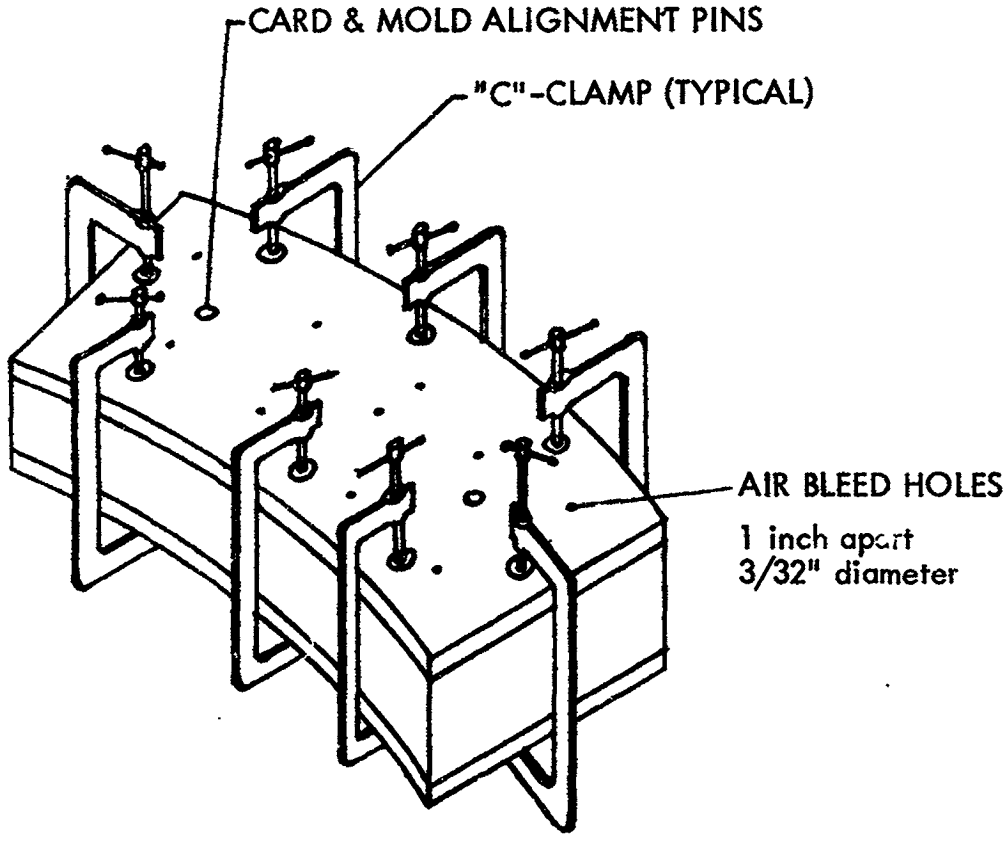

PRESSURE RELIEF HOLES
1 ELECTRONICS COMPONENTS
2 STAND-OFFS
3 PRINTED CIRCUIT CARD

Sketch B



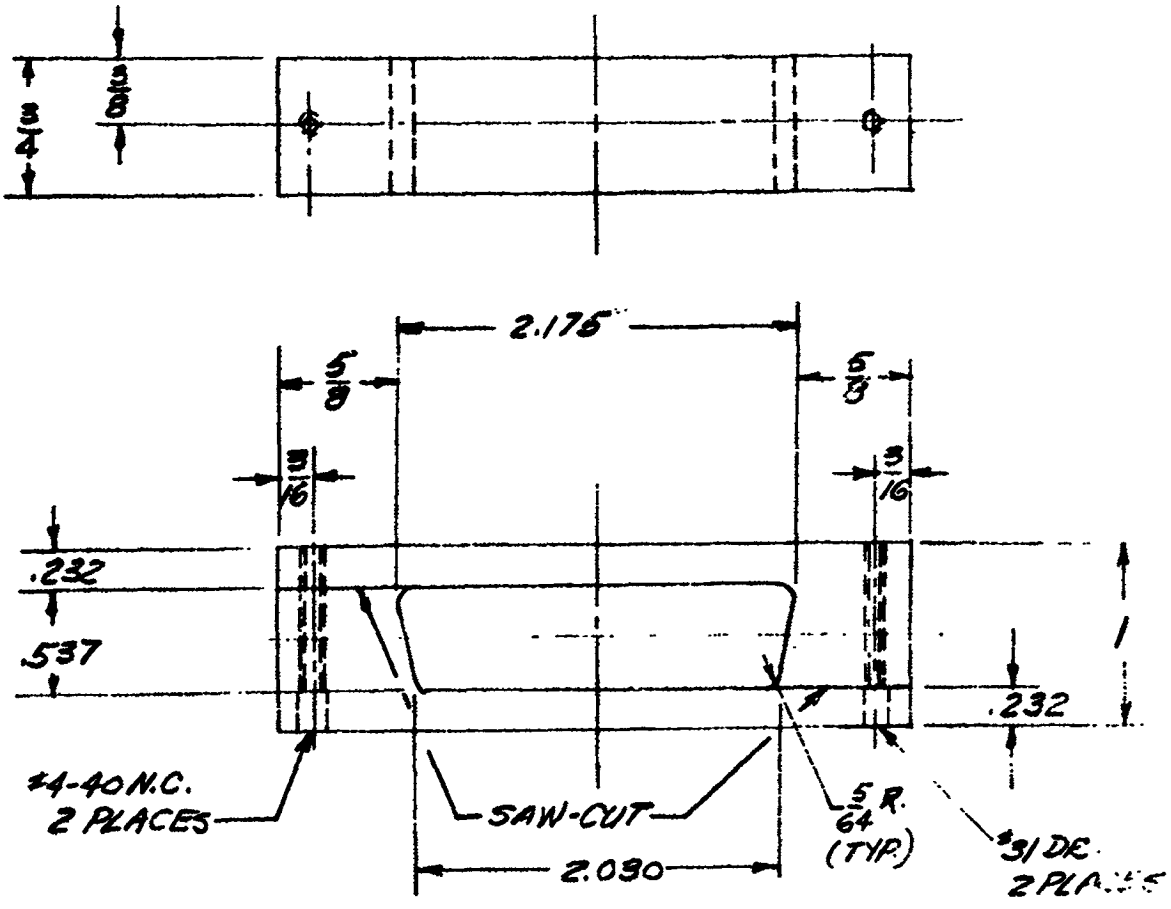
POTTING MIXER

Sketch C


CARD & MOLD ALIGNMENT PINS
"C"-CLAMP (TYPICAL)
AIR BLEED HOLES
1 inch apart
3/32" diameter

Sketch D

NOTE
1. 63√ MACHINE FINISH
2. FOR 50 PIN PLUG



POTTING MOLD, CANNON PLUG
MAT'L - TEFLON

Sketch E

ENCAPSULATION, MATERIALS
PRC-STYCAST-LOCKTITE

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GENERAL PROCEDURE FOR USE OF STYCAST 2340M CASTING RESIN

1.0.1 Stycast resin is usually used as a pressure sealant. When used for this purpose it is used with PRC compound.

1.0.2 The connector should first be prepared as recommended in procedure 2.0.2. Procedures including pertinent notes from 2.0.2 through 2.1.0 should be followed with the exception of amount of PRC and cure.

1.0.3 Weigh out amount of PRC and accelerator to cover the back of pin connectors and soldered joints.

1.0.4 Brush on the PRC. Only a thin coating is required as the purpose of the PRC is to prohibit the penetration of Stycast through insert and pin case.

NOTE

Always wash hands before eating or smoking.
If accelerator contacts the skin, flush area with warm water.

1.0.5 After cure has been effected place Teflon mold around connector.

1.0.6 Separately weigh equal amounts of Stycast components A and B. Do not mix; leave each component part in its own container.

1.0.7 Heat components in oven at 125°F. Purpose of this procedure is to reduce the viscosity in order to facilitate mixing.

1.0.8 Using a clean spatula mix together compound parts A and B. Mix for approximately four (4) minutes. An even mix will have a brick red color without any gray streaks.

1.0.9 Cast into mold over wire and connector pins that were previously coated with PRC compound.

1.1.0 Cure overnight in over at 150°F.

NOTE

Overnight cure is recommended if connector is to be subjected to pressure during use. If connector is not to be pressurized a fast cure of four (4) hours at 200°F is adequate.

GENERAL INSTRUCTIONS FOR USE OF PRC COMPOUND

2.0.1 PRC compound is most generally used as a sealant against metallic particles and moisture, also as a prevention of wire fatigue under vibration.

In order to properly contain the sealant a mold must be used. An example of such a mold is shown on the attached sketch E page 13 Procedure E-I. It is recommended that the mold be made of Teflon as the sealant will not adhere to its surfaces.

2.0.2 The connector that is to be potted should be free of grease, oil or wax in order to insure good adhesion of the PRC. Cleaning may be accomplished with a small brush that has been dipped in acetone.

NOTE

Do not expose wire insulation and inserts to the acetone for any long period of time.

2.0.3 Separate the wires so as to allow a free flow of compound around all wires and soldered connections.

2.0.4 With a clean wood tongue depressor or putty knife stir the contents slowly until contents appear as a smooth creamy paste.

2.0.5 With a clean wood tongue depressor or putty knife stir the base compound until base material appears smooth.

NOTE

The ratio of base com ound to accelerator is 10 to 1 by weight.

2.0.6 Weigh out required amount of accelerator in paper cup.

2.0.7 Weigh out the required amount of base compound in paper cup.

2.0.8 Put the accelerator into the cup containing base material and hand mix slowly with a clean wood tongue depressor or clean spatula. Mix for approximately 5 to 7 minutes. Frequently scrape spatula so as to remove unmixed compound.

2.0.9 Allow air cure for a minimum of 30 minutes.

2.1.0 Cure by means of heat lamp or drying oven when applicable.

NOTE

Do not cure over 130°F as compound may expand and cause the texture of the sealant to become porous.

NOTE

PRC cures to a tack free condition within twenty-four (24) hours if temperature is maintained at 77°F and the relative humidity at 50%. The effect of humidity is indicated by the fact that compound will become tack free 20 times as fast at 95% relative humidity.

GENERAL INSTRUCTIONS FOR USING LOCKTITE SEALANT

3.0.1 Locktite sealant is generally used on all critical fasteners at final assembly of payload structures. It is also used on threaded terminals on battery packs.

The primary purpose of using locktite is to enhance resistance of mechanical connection to vibration and eliminate loose electrical connections in service resulting in increased mechanical strength of circuit.

3.0.2 Screws to be locktited should be free of grease, oil, or wax.

The primary purpose of using locktite is to enhance resistance of mechanical connection to vibration and eliminate loose electrical connections in service resulting in increased mechanical strength of circuit.

3.0.3 Place small amount of locktite into a small clean dish.

3.0.4 Apply locktite to screw thread with a small clean brush. Only a very small amount is required, i.e., a maximum of one drop on an average size screw (6-32).

3.0.5 As an alternate method of application the screw that is to be locktited may be placed on a mechanical screw holder and dipped into the locktite in a dish. Again only a small amount is needed.

3.0.6 Screw the locktited screw into position at desired torque and allow to cure for approximately five (5) hours at 75°F before vibrating assembly.

3.0.7 Notes

1. Locktite C and CV are the most generally used grades at the GSFC in the assemblies of aluminum and/or magnesium.

2. Locktite cannot be used successfully on coated surfaces that have been anodized or Dow.

PROPERTIES OF ENCAPSULATION COMPOUNDS

SPACECRAFT INTEGRATION AND SOUNDING ROCKET DIVISION

This information was taken from Electronics Products Magazine and is not an original compilation.

Francis LeDoux

PROPERTIES OF ENCAPSULATING C

Manufacturer	Trade Name	Chemical Composition	Drying Time	Curing Time	Pot Life	Temperature Range	Cured State Hardness
[illegible] Alloys Inc. Brooklyn N. Y.	SHURBOND 192	Modified Epoxy	1 hr at room temp	4 hr at room temp	25 min	0 to 212°F	Hard, flexible Shore D – 80
Bacon Industries Inc. Watertown, Mass	P-11	Filled epoxy potting compound		8 hr at 212°F 40 hr at 300°F	90 min at 212°F		
	P-19	Filled epoxy potting compound		8 hr at 212°F 40 hr at 300°F	50 min at 212°F		
	P-14	Filled epoxy potting compound		8 hr at 212°F 40 hr at 300°F	60 min at 212°F		
	P-20	Filled epoxy potting compound		8 hr at 212°F 40 hr at 300°F	25 min at 212°F		
	P-38	Filled epoxy potting compound		8 hr at 212°F 40 hr at 300°F	60 min at 300°F		
	P-56	Filled epoxy potting compound		16 hr at 160°F	3 hr at 160°F		Shore D Hardness at 73°F – 93 at 160°F – 92
	P-58	Filled epoxy potting compound		16 hr at 160°F	2 hr at 160°F		
Carl H. Biggs Co. Santa Monica, Calif.	Helix potting compound X-474	Epoxy resin & hardener & microballoon additives		1 hr at 85°C 1 hr at 115°C	45 min (until baked)	–65 to 200°F	Shore D–80
	Helix potting compound X-476	Epoxy resin, hardener & silica		1 hr at 95°C 1 hr at 115°C	48 hr (until baked)	–65 to 200°F	Shore D–85
	Helix potting compound P-420	100% resin solids compound		2 hr at room temp or 1 hr at 150°F	About 1 hr to start jell	–80 to 300°F	Shore D–45
	Helix potting compound P-430	100% resin solids compound		2 hr at room temp or 1 hr at 150°F	About 1 hr to start jell	–80 to 350°F	Shore D–61
	Helix potting compound P-460	100% resin solids compound		2 hr at room temp or 1 hr at 150°F	About 1 hr to start jell	–80 to 350°F	Shore D–85
Biwax Corp. Skokie, Ill.	BIWAX F-6999	Epoxy		3 hr at 100°C	48 hr	Class A	
	BIWAX F-6998	Epoxy		½ hr at 180°F	5 hr	Class A	
	BIWAX E-715	Thermo-plastic				To 125°C	
	BIWAX A-1637	Thermo-plastic				To 135°C	
	BIWAX A-7070	Thermo-plastic				–55 to 100°C	

POUNDS

Viscosity	Acid/Salt/ Moisture Resist.	Dielectric Strength Constant	Specific Volume Resistivity	Components for use with	Special Features
poises - ookfield	Excellent	4.2 at 10^6 cps	1.5×10^{14} ohm-cm	Capacitors, resistors	Ex adhesion, flexibility
poises at 2°F		450 v mil	10^{14} ohm-cm		Ex adhesion, low creep
poises at 2°F		450 v mil	10^{14} ohm-cm		Ex adhesion, low creep
poises at 2°F		450 v mil	10^{14} ohm-cm		Low coeff expansion, high tensile strength
poises at 2°F		450 v mil	10^{14} ohm-cm		Low coeff expansion, high tensile strength, low creep
poises at 0°F		450 v mil	10^{14} ohm-cm		Crack resistant, low creep & coeff expansion, high tensile strength
poises at 0°F		450 v/mil	10^{14} ohm-cm		Superior thermal conductivity
to 30 poises 160°F		450 v mil	10^{14} ohm-cm		Low density, low coeff expansion, non-settling
,000 cps at °C	Excellent	330 v/mil at 25°C	1.0×10^{14} ohm-cm at 25°C		Extreme lightness
,000 cps at °C	Excellent	330 v/mil at 25°C	1.3×10^{14} ohm-cm		Thermal conductivity (BTU/HR/1°F/FT²/IN) 6.38
400 cps	Water absorption 24 hr = .00126%	100 – 5.37 10,000 – 4.81 100,000 – 4.55	6.6×10^{12} ohm-cm		Thermal conductivity (CAL/CM/Sec/°C) .00194
000 cps	Water absorption 24 hr = .004%	1,000 – 5.00	3.3×10^{12} ohm-cm		
,000 cps	Water absorption 24 hr = .006%	100,000 – 3.8	8.7×10^{14} ohm-cm		
000 cps			10^{14} ohm-cm	Transformers	
,000 cps			10^{14} ohm-cm	Coils	
			10^{13} ohm-cm	Capacitors	High volume resistivity at elevated temp
			10^{14} ohm-cm	Sweep transformers	Flame resistant
			10^{13} ohm-cm	Potting	Flexible and tough

PROPERTIES OF ENCAP

Manufacturer	Trade Name	Chemical Composition	Drying Time	Curing Time	Pot Life	Temperature Range
Chemetics, Inc. Cambridge, Mass.	162-18	Epoxy resin		24 hr at 75°F	30 min at 75°F	
	169-57	Epoxy resin		Three-stage	7 hr at 75°F	To 400°F
	230-08	Epoxy resin		16 hr at 289°F	Indefinite at 75°F	To 275°F
CIBA Products Fairlawn, N. J.	Araldite 6010 Hardener 906 BDMA	Epoxy resin liquid anhydride Tertiary amine		4 to 8 hr at 150°C–2 to 4 hr at 200°C	8 hr at 25°C	0 to 260°C
	Araldite 502 Hardener 951	Epoxy resin, amine hardener	24 hr at 25°C	6 hr at 40°C	30 min for 1 pound	0 to 100°C
	Araldite 6060 Hardener 901	Epoxy resin solid anhydride		16 hr at 120°C or 8 hr at 160°C	60 min at 130°C	0 to 130°C
	Araldite 502 Hardener MDA	Epoxy resin m-phenedian-iline		8 hr at 80°C or 2 hr at 120°C	8 hr at 40°C	0 to 120°C
Daylen Company South Gate, Calif.	Thermoplaz	Filled organics	8 hr	1 hr at 375°F	3 hr	–250 to 550°F
	Thermoplaz	Filled inorganics	3 hr	6 hr at 180°F	2 hr	–250 to 1250°F
Dennis Chemical Co. St. Louis, Mo.	6801 epoxy base E-H hardener	Epoxy	24 hr at 77°F	1 hr at 200°F 3 hr at 400°F	8 hr at 77°F	0 to 310°F
	No. 6704–A Epoxy No. 6704–B Hardener	Filled epoxy	8 hr at 77°F	7 days at 77°F 120 min at 150°F	105 min at 77°F	0 to 140°F
	No. 6803 epoxy base No. E-C Hardener	Modified epoxy	24 hr at 77°F	16 hr at 77°F 2 hr at 200°F	12½ hr at 77°F	0 to 200°F
	No. 6805 epoxy base No. E-F Hardener	Filled epoxy	2 hr at 77°F	7 days at 77°F	40 min	0 to 275°F
	No. R-103-1514D epoxy base No. R-103-1514E epoxy hardener	Modified epoxy		2 hr at 200°F 15 hr at 500°F	110 min at 175°F	0 to 560°F
Dow Corning Corp. Midland, Mich	Sylgard 183 resin	Silicone resin with filler		4 hr at 65°C	4 hr at 25°C	–85 to 482°F
	Silastic RTV 881	Silicone compound		24 hr at 25°C	3 hr at 25°C	–67 to 482°F
	304 molding compound	Silicone resin & inorganic fillers		2 to 3 min at 200 to 300°F		270 to 320°F
	Sylgard 182 resin			4 hr at 65°C	8 hr at 25°C with curing agent	–85 to 392°F

#1

ATING COMPOUNDS

Cured State Hardness	Viscosity	Acid·Salt Moisture Resist.	Dielectric Strength Constant	Specific Volume Resistivity	Components for use with	Special Features
3–7000 psi	4,000 cps at 75°F		4.20	4 x 10^{16} ohm-cm		Low viscosity, room temp cure
3–10,500 i	30,000 cps at 75°F					High heat resistance
3–9,000 i	47,000 cps at 75°F		4.0		Transformers	Low shrinkage
ard	2,000 cps at 25°C		400 v mil	1 x 10^{16} ohm-cm		High temp resistance
ard	1,000 cps at 25°C	Acid, salt resistant, low water absorption	400 to 500 v mil	1 x 10^{16} ohm-cm		Excellent adhesion
ard	140 cps at 120°C	Water absorption 0.3%/1 hr at 100°C	400 v mil	6.5 x 10^{15} ohm-cm		Low shrinkage, no exotherm
ard	800 cps at 40°C	Low water absorption, acid salt resistant	420 v mil	3.8 x 10^{14} ohm-cm		Tough and chemical resistant
lard, 120 ockwell	2,000 cps	Acid, salt resistant, low moisture absorption	500 v mil	10^{14}	Diodes, solenoids, transistors, semiconductors	
ard, 170 ockwell	2,000 cps	Acid, salt resistant, absorbs moisture	250 v/mil	10^{10}	Diodes, solenoids, transistors, semiconductors	
ard, hore D–93	12,000 cps at 77°F – 800 cps at 110°F	Excellent	400 v/mil	2.6 x 10^{15} ohm-cm	High temp operating electrical components	High heat distortion temp, good chemical resistance
ard, hore D–60	5,400 cps at 77°F	Excellent	300 v mil	10^{13} ohm-cm	Potting coils and transformers	Low toxicity and shrinkage, ex thermo-shock properties
lard, hore D–60	230 cps at 77°F	Acid salt resistant, low water absorption	390 v/mil	10^{13} ohm-cm	Laminating, capacitors and intricate electrical pottings	Low viscosity, long pot life, good adhesion
lard, hore D–95	5,000 cps at 77°F	Excellent	370 v/mil	4 x 10^{14} ohm-cm	Potting and encasing transformers	Good heat transfer and adhesion
lard, hore D–92	2,000 cps at 160°F	Excellent	400 v/mil	0.38 x 10^{16} ohm-cm	High temp electrical potting applications	Long pot life, ex electrical properties
hore A–45	8,000 cps at 25°C – 5,000 cps with curing agent added	Acid salt resistant, low water absorption	550 v/mil	2 x 10^{15} ohm-cm	Potting or embedding all electrical components	Tough, easy repairing, heat resistant
hore A–85	50,000 cps	Ex to all except strong oxidizing acids	550 v/mil ASTM D-149	1 x 10^{14} ohm-cm	All	Wide service temp range, ex dielectric properties
90, D 785		Ex to all except strong oxidizing acids	380 v/mil	5 x 10^{14} ohm-cm	Diodes, transistors	Shock and flame resistant
hore A–40	5,000 cps at 25°C	Ex to all except strong oxidizing acids	550 v/mil	2 x 10^{15} ohm-cm	All	Transparency, easy repairing, heat resistant

#2

PROPERTIES OF ENCAP

Manufacturer	Trade Name	Chemical Composition	Drying Time	Curing Time	Pot Life	Temperature Range
Emerson & Cuming, Inc. Canton, Mass.	STYCAST 2651	Filled epoxy		8 hr at 70 F 16 hr at 200 F	½ hr at 70 F 8 hr at 70 F	−70 to 350°F
	STYCAST 2850 FT	Filled epoxy		8 hr at 70 F 16 hr at 200 F	½ hr at 70 F 8 hr at 70°F	−80 to 400 F
	STYCAST 1467	Filled epoxy		8 hr at 70 F 16 hr at 200 F	½ hr at 70 F 8 hr at 70°F	−100 to 300°F
	ECCOFOAM FP	Polyurethane closed cell		2 hr at room temp 150°F 1 hour		−95 to +150°F
	ECCOFOAM FPH	Polyurethane closed cell		6 hr at room temp Hi-temp post cure 300 F		−95 to +300°F
	ECCOCOAT 36-D	Filled epoxy		½ hr at 350 F	6 mos at 70°F	−70°to 450 F
	STYCAST 1210	Filled epoxy		2 hr at 250°F	3 days at 70°F	−100° to 350°F
	STYCAST 1264	Unfilled epoxy		48 hr at 70 F 8 hr at 110°F	2 to 4 hr in small masses	−70 to 250°F
Epoxy Products Irvington, N. J.	Molding compound MP 2000	Epoxy, mineral filled, 1 component		15 sec to 3 min		−65 to 500°F
	E Form pellets 5099	Epoxy, mineral filled		12 hr at 100°C		To 175°C
	E Form pellets 6070	Epoxy, mineral filled		90 min at 125°C		To 200 C
General Electric Co. Silicone Prod. Dept. Waterford, N. Y.	RTV-11	Filled silicone 100% solids	8 to 12 hr−1% cat 3 to 5 hr .5% cat	48 hr .1% cat 24 hr .5% cat	4 to 6 hr .1% cat − 1 to 2 hr .5% cat	−65 to 600°F
	RTV-90	Filled silicone, no solvents	3 to 5 hr .1% cat 2 to 3 hr .5% cat	24 hr .1% cat 16 to 24 hr .5% cat	1 to 2 hr .1% cat ½ to 1 hr .5% cat	−65 to 600°F
	RTV-102	Filled silicone, no solvents	15 to 30 min	less than 24 hr		−65 to 400°F
	LTV-602	Filled silicone, no solvents	Controlled by type catalyst, quantity catalyst and temperature			−65 to 400°F
	RTV-20	Filled silicone, 100% solids	8 to 12 hr .1% cat 4 to 6 hr .5% cat	36 hr .1% cat 24 hr .5% cat	3 to 5 hr .1% cat 1 to 2 hr .5% cat	−65 to 600°F
	RTV-30	Filled silicone, 100% solids	7 to 10 hr .1% cat 2 to 4 hr .5% cat	24 hr .1% cat 8 to 12 hr .5% cat	3 to 5 hr .1% cat 1 to 2 hr .5% cat	−65 to 600°F

#1

TING COMPOUNDS

Cured State lardness	Viscosity	Acid/Salt/ Moisture Resist.	Dielectric Strength Constant	Specific Volume Resistivity	Components for use with	Special Features
rd, 90-100 ore D	10,000 cps	Excellent	455 v mil	5 x 10^{16} ohm-cm at 25 C 1 x 10^{13} at 150 C	Wide variety of casting, potting	Versatility
remely d, Shore 100	15,000 cps	Outstanding	455 v mil	5 x 10^{18} at 25 C	Large electrical castings	Low thermal expansion coeff
id, 90-100 ore D	8,000 cps at 25°C	Very good	400 v mil	1 x 10^{14} ohm-cm	Circuitry when flame and fume hazards are critical	Fire retardant in high degree
cu ft ore A-70					Electronic circuitry	Low bulk density
cu ft ore A-70					Electronic circuitry	Hi-temperature use
d, 3H, ncil hard-ss	Thixotropic Dip-Coat	Excellent	450 v mil	1 x 10^{14} ohm-cm	Capacitors and resistors	Fast cure capability
rd, Shore 30	10,000 cps	Excellent	460 v mil	1.2 x 10^{14} ohm-cm	Transformer potting	"Semi-flexible" high impact and thermal shock resistance
rd, tough ore D-80	1,000 cps	Excellent	300 v mil	1 x 10^{14} ohm-cm	Circuit module encapsulation	Optically clear, high impact strength, low viscosity
rd, TS 00 psi		Excellent		10^{16} at 25°C	Resistors, capacitors, semiconductors, coils	Low molding pressures
rco! 29	2,000 cps at 100°C	Good	400 v mil	1 x 10^{16} at 25°C	All components	Solid 1 component, pre-weighed
		Excellent	380 v mil	10^{15} at 25°C	Silicon Diodes	Flame resistant
astomer ore 45	120 poises	Resistant to most chemicals, low moisture absorption	630 v mil	6 x 10^{15} ohm-cm	Electrical & electronic equipment	White, great flexibility
astomer ore 60	12,000 poises	Resistant to most chemicals, low moisture absorption	600 v mil	1.3 x 10^{14} ohm-cm	All electrical & electronic equipment	Stiff paste, applied by spatula
astomer ore 28	Thixotropic	Resistant to most chemicals, low moisture absorption	.058"-550 v-mil .013"-425 v/mil	3.3 x 10^{15} ohm-cm	All electrical & electronic equipment	Adheres to anything, ready to use
astomer ore 15	12 poises	Resistant to most chemicals, low moisture absorption	.020"-41 kv/mil .100"-75 kv/mil	1 x 10^{14} ohm-cm	All electrical & electronic equipment	Complete transparency
astomer ore 50	300 poises	Resistant to most chemicals, low moisture absorption	650 v-mil	5 x 10^{13} ohm-cm	All electrical & electronic equipment	
lastomer ore 60	300 poises	Resistant to most chemicals, low moisture absorption	625 v/mil	1 x 10^{15} ohm-cm	All electrical & electronic equipment	

PROPERTIES OF ENCAP

Manufacturer	Trade Name	Chemical Composition	Drying Time	Curing Time	Pot Life	Temperature Range
General Electric Co. Silicone Prod. Dept. Waterford, N. Y.	RTV-40	Filled silicone, 100% solids	12 to 16 hr .1% cat 5 to 8 hr .5% cat	36 to 48 hr .1% cat 24 hr .5% cat	5 to 8 hr .1% cat 2 to 3 hr .5% cat	−65 to 500°F
	RTV-60	Filled silicone, 100% solids	8 to 12 hr .1% cat 4 to 6 hr .5% cat	24 hr .1% cat 24 hr .5% cat	3 to 5 hr .1% cat 1 to 2 hr .5% cat	−65 to 600°F
	RTV-77	Filled silicone 100% solids	6 to 10 hr .1% cat 2 to 3 hr .5% cat	36 to 48 hr .1% cat 24 hr .5% cat	2 to 3 hr .1% cat 1 to 2 hr .5% cat	−65 to 600°F
	RTV-88	Filled silicone 100% solids	8 to 12 hr .1% cat 4 to 6 hr .5% cat	24 hr .1% cat 16 to 24 hr .5% cat	4 to 6 hr .1% cat 1 to 2 hr .5% cat	−65 to 600°F
H. V. Hardman Co., Inc. Belleville, N. J.	EPOCAP	Filled or unfilled epoxy	1 min. at 200°F or 2 hr at 70°F	20 min at 200°F or 3 days at 70°F	20 min to 3 hr	0 to 300°C
	EPOLAST	Unfilled flexible epoxy	5 min at 175°F or 30 min at 70°F	30 min at 160°F or 3 days at 70°F	20 min to 1 hr	−65 to 250°F
Hysol Corp. Olean, N. Y.	Hysol Encapsulating C9-4183/H2-3561	Modified epoxy		24 hr at 25°C	80 min at 25°C	−55 to 130°C
Hysol Corp., Olean, N. Y.	C8-4143 H2-3404	Modified expoy		24 hr at 25°C	20 min at 25°C	−55° to 105°C
	Encapsulation Compound C17	Modified epoxy		4 hr at 125°C	1-1½ hr at 80°C	−55° to 80°C
	C9F-5151 H9-3569	Modified epoxy		16 hr at	40 to 50 min at 25°C	−65° to 130°C
	RTV 260	Modified silicone		24 hr at room temp	1-1½ to 2-2½ hr	−65° to 260°C
Marco Chem. Corp. Linden, N. J.	MR-28CS	Polyester resin		6 hr at 180°F	5 to 7 days	0 to 300°F
Mesa Plastics Co.	DIALL	Diallyl Phthalate resin based molding compound		1 to 3 min at 300°F	1 year	400 to 500°F
	EPIALL	Epoxy resin-based molding compound		300 to 350°F 1 to 5 min at		To 500°F
	POLYALL	Alkyd resin-based molding compound		30 sec at 300°F		To 400°F

#1

ATING COMPOUNDS

Cured State Hardness	Viscosity	Acid/Salt/ Moisture Resist.	Dielectric Strength Constant	Specific Volume Resistivity	Components for use with	Special Features
lastomer hore 55	450 poises	Resistant to most chemicals, low moisture absorption	600 v mil	1 x 10^{14} ohm-cm	All electrical & electronic equipment	White color
lastomer hore 60	550 poises	Resistant to most chemicals, low moisture absorption	600 v/mil	1 x 10^{14} ohm-cm	All electrical & electronic equipment	Also available in aerosol
lastomer hore 50	8,000 poises	Resistant to most chemicals, low moisture absorption	650 v/mil	1 x 10^{15} ohm-cm	All electrical & electronic equipment	White thixotropic applied by caulking gun
lastomer ıore 65	10,000 poises	Resistant to most chemicals, low moisture absorption	575 v/mil	1 x 10^{14} ohm-cm	All electrical & electronic equipment	Thixotropic applied by caulking gun
ard	5,000 cps	Excellent	Excellent	Excellent	Almost all	Excellent stability
lexible, ıore D–30 ıd up	1,500 cps	Excellent	Good	Good	Semiconductor modules	Flexibility
ıore D–83	. . 0 at 25°C	Resistant to most	4.21 at 100 kc at 30°C	3.99 x 10^{14} ohm-cm at 30°C	Where impact strength is needed around lead wires	General purpose, resilient, room cure
ıore D–82	3,000 at 25°C	Resistant to most	4.? at 100 kc at 30°C	4.1 x 10^{14} ohm-cm at 30°C	All that require a rigid insulation system	General purpose, rigid, room cure
ıore D–70	250–750 at 80°C	Excellent to most	4.4 at 100 kc at 30°C	3.8 x 10^{13} ohm-cm at 30°C	Military components	Meets MIL-I-16923D
ıore D–83	3,000 at 25°C	Excellent to most	4.52 at 100 kc at 30°C	4 x 10^{14} ohm-cm at 30°C	All components requiring low temp & flame resistance	Flame-out, room temp cure
ıore A–65	25,000 - 35,000	Resists all	3.6 at 30°C	3 x 10^{14} ohm-cm at 30°C	All electrical and electronic	Absorbs shock and vibration
ırcol 40	600 to 800 cps	Acid salt resistant, low water absorption	500 v/mil	7.1 x 10^{7} meg-ohms	Capacitors	
ırcol 65	Powder or flake form	Excellent	450 v/mil	10^{7} plus	Any molded part where nigh reliability is necessary	Excellent physical & electrical properties
ırcol 70	Powder or flake form	Excellent	450 v/mil	10^{7} plus	Any molded part where high reliability is needed	Excellent for components
arcol 65	Flake or putty	Fair	350 v/mil	10^{7} plus	Connectors	

#2

Manufacturer	Trade Name	Chemical Composition	Drying Time	Curing Time	Pot Life	Temperature Range
Minnesota Mining & Manufacturing Co. St. Paul, Minn.	"Scotchcast" Brand Resin No. 247	Filled epoxy		2 hr at 120 C	3 to 4 days	-55 to 130 C
	"Scotchcast" Brand Resin No. 241	Filled No. 235 epoxy		2 hr at 120 C	3 to 4 days at 23 C	-55 to 130 C continuous
	"Scotchcast" Brand Resin No. 2	Unfilled epoxy		1 hr at 60 C to 24 hr at 23 C	3 4 to 2 hr at 23°C	-55 to 105°C
	"Scotchcast" Brand Resin No. 3	Unfilled epoxy		2 hr at 120 C	3 to 4 days at 23°C	-55 to 105°C
	"Scotchcast" Brand Resin No. 5	Unfilled epoxy		1 hr at 60 C to 24 hr at 23°C	3 4 to 2 hr at 23°C	-55 to 105°C
	"Scotchcast" Brand Resin No. 8	Unfilled epoxy		1 2 hr at 95°C	1 to 2-1 2 hr at 23°C	-55 to 130°C
	"Scotchcast" Brand Resin No. 235	Unfilled epoxy		2 hr at 120 C	3 to 4 days at 23°C	-55 to 130°C continuous
	"Scotchcast" Brand Resin No. 232	Filled brown epoxy		1 hr at 60°C to 24 hr at 23°C	3 4 to 2 hr at 23°C	-55 to 105°C
	"Scotchcast" Brand Resin No. 10	Filled thixotropic epoxy		1 2 hr at 95°C to 24 hr at 23°C	1 to 2-1 2 hr at 23°C	-55 to 130°C
	"Scotchcast" Brand Resin No. 9	Filled No. 8 epoxy		1 2 hr at 95°C or 24 hr at 23 C	1 to 2-1 2 hr at 23°C	-55 to 130°C
	"Scotchcast" Brand Resin No. 248	Filled thixotropic epoxy		2 hr at 120°C	3 to 4 days at 23°C	-55 to 130°C
	"Scotchcast" Brand Resin No. 250	Unfilled epoxy		2 hr at 120°C	3 to 4 days at 23°C	-55 to 130°C
	"Scotchcast" Brand Resin No. 251	Filled No. 250 epoxy		2 hr at 120°C	3 to 4 days	-55 to 155°C
	"Scotchcast" Brand Resin No. 252	Filled thixotropic epoxy		2 hr at 120°C	3 to 4 days	-55 to 155°C
	"Scotchcast" Brand Resin No. CRP 253	Filled thixotropic		2 hr at 120°C	3 to 4 days at 23°C	-55 to 130°C
	"Scotchcast" Brand Resin No. 603	Filled powder - one part		3 to 4 hr at 90°C	3 to 4 hr at 90°C	
	"Scotchcast" Resin No. XR-5017	Unfilled silicone rubber foam		1 2 hr at 120°C or 24 hr at 23°C	1/2 hr at 23°C	-75 to 260°F
Natl Engrg Prod. Inc. Washington, D. C.	Castiplast #11	Modified epoxy		Overnight at room temp	45 min	-55 to 110°C
	Castiplast #474	Modified epoxy		Overnight at room temp	45 min	-55 to 110°C
	Castiplast #594	Filled epoxy		Overnight at room temp	2-1/2 hr	-55 to 110°C

#1

LATING COMPOUNDS

Cured State Hardness	Viscosity	Acid/Salt/ Moisture Resist.	Dielectric Strength Constant	Specific Volume Resistivity	Components for use with	Special Features
emi-flexible hore D–65	75,000 cps at 23°C	Very good	400 v mil	10^{14} ohm-cm at 23°C	Those desiring fast flameout characteristics	
emi-flexible hore D–65	30,000 cps at 23°C	Very good	375 v mil	10^{14} ohm-cm at 23°C	Small components to large transformers	Thermal shock resistant
Rigid 5 Barcol	25,000 cps at 23°C	Very good	325 v mil	10^{14} ohm-cm at 23°C		Self extinguishing-reliable
Rigid Barcol	1,000 cps at 23°C	Very good	350 v mil	10^{13} ohm-cm at 23°C		Low velocity superior properties
igid 5 Barcol	2,200 cps at 23°C	Very good	325 v mil	10^{14} ohm-cm at 23°C		Self extinguishing-excellent properties
emi-flexible hore D–70	5,700 cps at 23°C	Very good	430 v mil	10^{4} ohm-cm at 23°C	Motor stators & coils, p-c boards	Shock resistant
emi-flexible Shore D–55	4,400 cps at 23°C	Very good	325 v mil	10^{14} ohm-cm	All	Stays flexible
Rigid 0 Barcol	100,000 cps at 23°C	Very good	375 v mil	10^{14} ohm-cm at 23°C	Battery and condenser sealant	Thick putty material used for sealing
emi-flexible hore D–75	High paste	Very good	450 v mil	10^{14} ohm-cm at 23°C	All	Shock resistant, non-sagging properties
emi-flexible hore D–75	25,000 cps at 23°C	Very good	450 v/mil	10^{14} ohm-cm at 23°C		Low exothermic heat rise during cure
emi-flexible Shore D–65	High thixotropic	Very good	400 v mil	10^{14} ohm-cm at 23°C	All	High temp stability
Rigid 25 Barcol	2,000 cps	Very good	350 v/mil	10^{15} ohm-cm at 23°C		Fine impregnant, Pour like machine oil
Rigid 5 Barcol	200 cps at 120°C	Very good	450 v/mil	10^{15} ohm-cm at 23°C	Transformers and other components	High temp resistant
Rigid 45 Barcol	Medium thixotropic	Very good	450 v/mil	10^{15} ohm-cm at 23°C		
Semi-flexible Shore D–64	High thixotropic	Very good	375 v/mil	10^{4} ohm-cm at 23°C		
Rigid closed cell		Very good	50 v/mil		Insulated motor	
Flexible closed cell	20,000 cps at at 25°C	Very good	75 v/mil	1.8×10^{13} ohm-cm at 23°C	Coating circuit boards & panels; components	High temp foam binds to most materials
Hard	900 cps	Excellent	340 v/mil	10^{13}		Ex air bubble release
Hard	Thixotropic	Excellent	340 v/mil	10^{13}		No sag or running during cure
Hard	20,000 cps	Excellent	460 v/mil	10^{13}		Very low exotherm

#2

PROPERTIES OF ENCA

Manufacturer	Trade Name	Chemical Composition	Drying Time	Curing Time	Pot Life	Temperature Range
[illegible]	Castiplast #892	Modified epoxy		Overnight at 40 C	5-1 2 hr	−55 to 100 C
	Castiplast #894	Filled epoxy		Overnight at room temp	25 min	−55 to 130 C
[illegible] Cranston, R. I.	GR151	Unfilled polysulfide epoxy	4 hr at 25 C	4 hr at 70 C	3 hr	−65 to 150 C
	GR204	Unfilled polysulfide epoxy	60 min at 25 C	4 hr at 25 C	30 min at 25°C	−65 to 135°C confined
	GR401 20	Unfilled epoxy	30 min	3 hr at 25°C	20 to 30 min	−50 to 150°C
Pacific Resins & Chemicals, Inc. Seattle, Wash.	EMC 90-B-1	Mineral filled epoxy		15 to 45 sec		−65 to 250°C
Products Research Co. Burbank, Calif.	PR-905	Modified epoxy		1 hr at 180°F	25 min	−65 to 300°F
	PR-906	Modified epoxy		1 hr at 180°F	25 min	−65 to 300°F
	PR-1538	Polyurethane		4 hr at 180°F	1 hr	−70 to 300°F
RCL Electronics Inc. Riverside, N. J.	BJP-9	Epoxy	10 hr	3 hr	30 min	−85 to 250°C
Seal-Peel, Inc. Royal Oak, Mich.	SEAL-STOP	Cellulose acetate butyrate	Less than 1 min		Weeks	
The Sterling Varnish Co. Sewickley, Pa.	E-602-41	Pourable filled epoxy	1 hr at 150°C	5 hr at 150°C	1 hr at 130°C	−130 to 150°C
	U-300	Thixotropic filled epoxy	1 2 hr at 150°C	16 hr at 150°C	4 to 6 hrs at 25°C	0 to 180°C
	E-450-46A	Thixotropic filled epoxy	12 to 16 hr at 25°C	12 hr 25°C or 2 hr 100°C	2 to 3 hr at 25°C	−55 to 130°C
	E-653-46	Pourable filled epoxy	12 to 16 hr at 25°C	22 hr at 25°C or 2 hr 110°C	2 to 3 hr at 25°C	−55 to 130°C
Techform Labs, Inc. Venice, Calif.	ETC-1	Filled epoxy		Overnight at 72°F	1 to 2 hr	0 to 250°F
	ETC-2	Filled epoxy		2 to 3 hr at 300°F	Several days at 72°F	0 to 350°F
Technicraft Co. Boston, Mass.	"Chemiglas" type RTC-B	Liquid polyester resin	30 min to 48 hr	Jell in 7 min to 20 min	Varies with amts of catalyst	
Silicone Div. Union Carbide Corp. New York, N. Y.	UCAR K-1850 RTV Silicone rubber	Filled silicone polymer	Tack free surf 1 2-10 hr at 25°C (controllable)	1/21-20 hr at 25°C (controllable)	Same as curing time	−90 to 550°F
Western Coating Co. Royal Oak, Mich.	MASKCOAT #2	Cellulose acetate butyrate	less than 1 min		Several weeks	

LATING COMPOUNDS

Cured State Hardness	Viscosity	Acid Salt Moisture Resist.	Dielectric Strength Constant	Specific Volume Resistivity	Components for use with	Special Features
Rubbery	500 cps	Fair	450 v mil	$10^{}$		Retains rubber, after molded,
Hard	8,000 cps	Excellent	410 v mil	10^{12}		Self extinguishing, high thermal shock resistance
Rigid 75-85 Type A 10 sec readings	Low, 55 poises	Acid and salt resistant, low water absorption	435 v mil	1.5×10^{13}	Capacitors, resistors, transistors, printed circuits	Excellent adhesion, high impact at -60° C
Rubbery 60-70 Type A 10 sec readings	Very low, 22 poises at 25°C	Acid and salt resistant, low water absorption	250 v mil	1.5×10^{12}	Capacitors, resistors transistors, printed circuits	Excellent adhesion high impact at -60° C
Hard, 97 M Rockwell	Low, 750 cps	Acid and salt resistant, low water absorption	4.2 at 60° C 3.5 at 106° C	10^{15} ohm-cm	Capacitors, resistors	Excellent adhesion
Rockwell 110 M	Solid, granular	Acid salt resistant, low water absorption	400 v mil	10^{16} ohm-cm	All	High flow under low pressure
Semi-flexible Shore D-65	20 poises	Acid, salt resistant, low water absorption	300 v mil	5×10^{12} ohm-cm		Tough, semi-flexible, low volume shrinkage
Semi-flexible Shore D-75	20 poises	Acid salt resistant, low water absorption	350 v/mil	6×10^{12} ohm-cm		Tough, semi-flexible, low volume shrinkage
Flexible Shore A-80	100 poises	Fair acid, salt resistance	750 v mil	1×10^{13} ohm-cm		Tough, flexible, cold-flow resistance
Hard, Rockwell 26 M	Low	Acid salt resistant, non-higroscopic	10,000 v mil	10^{16} ohm-cm	Capacitors, resistors	High temp. operation
			500 v/mil			
Semi-rigid Shore D-80	2,000 cps at 135°C	Excellent	400 v/mil	10^{15} ohm-cm	Transformers, switchgear	Ex elec properties, low coeff of expansion
Rigid Shore D-85	Thixotropic paste	Excellent	350 v mil	10^{15} ohm-cm	Rotating field coils	Retention of high bond at elevated temp
Semi-rigid Shore D-80	Thixotropic paste	Excellent	350 v/mil	10^{14} ohm-cm		Brushable, 100% solid protective coat
Semi-rigid Shore D-80	2,000 cps at 25°C	Excellent	350 v/mil	10^{14} ohm-cm	Coils, transformers, motors	Machinable
Shore D-88	20,000 cps at room temp	Good chemical resistance	350 v/mil	10^{15} ohm-cm	Transformers	
Shore D-65	10,000 cps	Good chemical resistance	350 v/mil	10^{15} ohm-cm	Transformers	Long shelf life, high shock resistance
Rockwell M Scale 115	400 cps	Excellent-except concentrated acids & alkals	530 v/mil			
Shore A-50	(uncured) Nom 55,000 cps can be lowered to 20,000 cps with diluent	Salt resistant, low water absorption	1,000 v/mil, 30 mil slab	10^{14} - 10^{16} ohm-cm 75°C	All potting & encapsulating applications	Broad temp range, repairable, bondable, with primer
			500 v/mil			

#2